PREDICTION OF METHYL BROMIDE FLUX FROM AREA SOURCES USING THE ISCST MODEL

By

L. J. Ross, B. Johnson, K. D. Kim, and J. Hsu

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ENVIRONMENTAL HAZARDS ASSESSMENT PROGRAM

STATE OF CALIFORNIA
Environmental Protection Agency
Department of Pesticide Regulation
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EXECUTIVE SUMMARY
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California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Hazards Assessment Program

PURPOSE

The Department of Pesticide Regulation Environmental Hazards Assessment Program compared emission rates (flux) of the pesticide methyl bromide measured in the field, with flux estimated from a mathematical model using a back-calculation method. Methyl bromide is a source of stratospheric ozone depletion, and has the potential to pose a hazard to human health. Flux can be used to estimate the agricultural contribution of methyl bromide to ozone depletion, and to estimate methyl bromide air concentrations at any distance from a treated field. Since flux data can be expensive to collect and are not typically measured in the field, this study was conducted to determine whether flux can be estimated using more readily available downwind air concentrations.

BACKGROUND

Methyl bromide is a gas used as a pesticide for structural pest control and control of pests of stored commodities, and as a preplant soil fumigant to control fungi, insects, nematodes, and weeds. It is extensively used in California.

Methyl bromide has been identified as one source of stratospheric ozone depletion, which can increase the amount of the sun's radiation reaching the earth's surface. Increased radiation can result in potential increases in certain skin cancers, cataracts, tropospheric ozone, damage to crops and aquatic organisms, and weathering of outdoor plastics, as well as suppression of the human immune system.

A review of animal studies conducted to evaluate various health effects has shown that methyl bromide also has the potential to cause neurotoxic and developmental effects. As a result, use practices have been and may continue to be modified to ensure that there is an adequate margin of safety to protect human health.

Flux is the amount of a chemical emitted from a given area over a given time period. Flux from pesticide applications can be compared to flux from other man-made and natural sources of methyl bromide to determine the significance of pesticidal uses on ozone depletion. Flux data are also used in mathematical models, such as the widely used Industrial Source Complex Short Term (ISCST) model, to estimate downwind air concentrations of methyl bromide at any offsite location from a treated field. Downwind air concentrations can then be used to characterize potential human exposure to methyl bromide in air and to establish buffer zones, if needed, around treated areas.

The difficulty is that flux data can be expensive to collect and are not widely reported in the literature. This study was conducted to determine whether downwind air concentrations of methyl bromide can be used to accurately back-calculate flux using the ISCST model. If this procedure proves useful, then it could be used to estimate flux for use in models to determine the contribution of methyl bromide to ozone depletion, off-site air concentrations at any downwind location, and the size of buffer zones if needed.

STUDY METHODS

Two commercial lettuce fields, located approximately 10 miles east of the city of Monterey, California, were used in this study. A 10-acre field was tarped immediately following application and a second 15-acre field remained untarped following application. A mixture of methyl bromide and chloropicrin in a 67%/33% and a 98%/2% ratio was applied to the tarped and untarped fields, respectively. The fumigant was injected at a depth of 10 to 12 inches in both fields. The tarped field was treated with 235 pounds per acre of actual methyl bromide on October 26, 1992, and the untarped field with 177 pounds per acre of actual methyl bromide on October 27, 1992. On the untarped field, soil was bedded over the fumigation injection line.

A meteorological station was placed between 23 and 32 feet from the edge of each field. Wind speed and direction, temperature, and relative humidity data were collected over 15-minute intervals. Rainfall data were collected at the tarped field only.

Levels of methyl bromide were sampled at eight locations off-site from each field. Four locations were 23 feet from the field, 90° apart, and the other four, about 160 feet from the field on a 45° angle offset from the other samplers.

During application, air samplers were run for the duration of the application period which took approximately five and four hours in the tarped and untarped fields, respectively. Subsequently, air sampling was conducted simultaneously with flux measurements. On the day of application, samples were taken at four-hour intervals and on subsequent days, at four- and eight-hour intervals.

Back calculations were done with the ISCST model using stability class D (which indicates a given amount of mixing or movement of air between the soil surface and either a 600 foot or other specified elevation), hourly wind speed and direction, ambient air temperature, and an assumed arbitrary area-corrected flux value.

The aerodynamic method was used by another researcher (Majewski) to measure flux of methyl bromide. Air samples and wind speed measurements were taken at 8, 12, 20, 31, 49, and 79 inches above the soil surface at both fields. Flux was calculated as the product of differences in methyl bromide air concentrations and wind with respect to height, divided by a meteorological stability factor.

Flux measurements made during each sampling period and corresponding back-calculated flux estimates were each aggregated into daily time-weighted averages, which were compared statistically.

RESULTS

For both the tarped and untarped fields, there was a significant correlation between measured and predicted 24-hour flux at the one percent level. Although the back-calculation procedure underpredicted flux in both tarped and untarped fields, the predicted flux values in tarped fields were not significantly different from measured flux values. In untarped fields, the predicted values were significantly different from the measured values.

The tendency of the back-calculation procedure to underpredict flux resulted, in part, from the tendency of the ISCST model to overestimate downwind air concentrations by 13 percent. Adjusting for this discrepancy improved the relationship between measured and predicted flux, but that relationship was still significantly different for the untarped field, suggesting other causes for the discrepancy.

Another explanation may be related to the way the ISCST model divides up the area source of methyl bromide into subsources. This could result in locally higher estimated air concentrations especially close to the source.

Another possible reason for underpredicting flux may be the use of the "D" stability class throughout the entire study. Use of this stability class was based on an estimate of stability conditions. Uncertainty over the degree of cloudiness in the first 1-2 days after application might have led to an error in stability class selection. An error of this nature could cause a substantial change in model predictions. For example, a sample calculation using stability class "C" (more air mixing) reduced estimated air concentrations by 38 percent, illustrating the importance of stability class to the model back-calculation procedure. classification of "C" stability. Therefore, planning for future work should include more consideration of stability class estimation.

CONCLUSION

When compared to measured flux, back-calculated flux using the ISCST model were systematically lower because the model overestimates off-site air concentrations. Although flux will be systematically underestimated, off-site air concentrations can be reliably estimated since the model proportionately overestimates off-site air concentrations. These offsetting effects imply that the judicious use of 24-hour average, back-calculated flux values should provide a reasonable basis for estimating off-site air concentrations and establishing buffer zones, if necessary.

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DISCLAIMER

The mention of commercial products, their source, or use in connection with material reported herein is not to be construed as an actual or implied endorsement of such product.

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ABSTRACT

Growing concern about atmospheric exposure to pesticides has led to increased air monitoring in California to evaluate this potential route of exposure. Air monitoring data typically consist of measurements made downwind from point or area sources. The utility of monitoring at fixed stations is limited for establishing buffer zones to protect neighboring populations from pesticide exposure. A modeling approach designed to utilize these data would provide the flexibility needed to establish buffer zones. The Industrial Source Complex Short Term (ISCST) model is a gaussian plume dispersion model which predicts air concentrations downwind from point or area sources using emission rates (flux) and meteorological conditions as model inputs. However, flux data are typically not collected in the field nor available in the literature. In order to use the field data currently available, we developed a procedure using downwind air concentrations and the ISCST model, to back-calculate flux. In this field trial, methyl bromide (MeBr) concentrations were measured downwind from two area sources. In addition, MeBr flux was measured concurrently by cooperators conducting an independent study. Downwind concentrations, together with actual meteorological data, were used as inputs to the ISCST model. Flux of MeBr was then back-calculated using a two step process: 1. an arbitrary flux value of 100 ug m^{-2} s^{-1} was used as an initial input value. Air concentrations predicted downwind by the ISCST model were then regressed on air concentrations measured offsite. 2. The resultant regression coefficient was then used to adjust the arbitrary flux to a back-calculated flux. Using another regression analysis, back-calculated and measured flux rates were found to be significantly correlated, indicating this approach may be suitable for indirect estimation of flux. Implications for the use of this method in establishing buffer zones designed to protect human health are discussed.

INTRODUCTION

Methyl bromide (MeBr) is a halogenated, hydrocarbon gas used as a pre-plant soil fumigant to control fungi, insects, nematodes, and weeds. It is also used for structural pest control as well as a fumigant for harvested grains, fruits, and nuts. MeBr is used extensively in California, totaling over 8,500,000 Kg in 1992 alone (CDPR, 1992). Concern about MeBr and its role in the destruction of the earth's ozone layer has raised questions about anthropogenic sources, emission rates (flux) from those sources, and transport of this material into the stratosphere (Andersen et al., 1992).

Much of the MeBr generated at the earth's surface is natural in origin, while an estimated 25±10% is believed to be generated by anthropogenic sources (Andersen et al., 1992). Of the anthropogenic uses for MeBr, 80% is as a pre-plant soil-fumigant. Flux from soil fumigations have only recently been investigated in a field chamber study (Yagi et al., 1993), in a simulation study (Reibel, 1994), and with the aerodynamic method (Majewski et al., 1995). Accurate flux measurements, in part, are necessary to determine the potential impact of MeBr use on the depletion of stratospheric ozone.

Although necessary for specific investigations, e.g. above, the routine measurement of flux from area sources could be prohibitively expensive. Meanwhile, the need for such data has increased, particularly in California where there is growing concern about the atmospheric exposure of humans to pesticides. This concern has led to state legislation requiring the California Department of Pesticide Regulation (DPR), in cooperation with the California Air Resources Board, to gather data about atmospheric concentrations of pesticides used in the state. These data are then reviewed by DPR to determine if there is a need to restrict the use of a given pesticide. In addition, if air concentrations in the immediate vicinity of agricultural sources are found above established health limits, protective buffer zones may either be estimated through additional sampling, or through modeling.

Modeling can be an inexpensive alternative to actual field measurement and provides the flexibility needed for establishing buffer zones. To predict downwind concentrations from point or area sources, an emission source strength is generally required. Emission rates, however, are generally not available in the literature for area sources, nor are they typically measured in the field and therefore must be estimated in the modeling process. In the absence of such data, a procedure using the data more commonly available to

DPR, downwind air concentrations, was developed (see below).

A model widely used for estimating atmospheric concentrations of a chemical downwind from a source is the Industrial Source Complex Short Term model (ISCST; Wagner, 1987). The basis for the ISCST model is the gaussian plume dispersion equation for estimating downwind air concentrations:

$$C(x,y,z) = \frac{Q \cdot K(\sigma_y, \sigma_z)}{3.14 \cdot u \cdot \sigma_y \cdot \sigma_z} \quad (1)$$

where C(x,y,z) is the air concentration (μg m^{-3}) at downwind distance x (m), centerline offset y (m) and height z (m); Q is emission rate (or flux in μg s^{-1}); K is an empirical adjustment factor depending on x, y, z and the standard deviation of lateral (σ_y , m) and vertical (σ_z, m) concentration distribution; and u is wind speed (m s^{-1}). An important feature in equation 1 is the proportional relationship between flux and air concentration. A consequence of this relationship is that under conditions of constant flux, it should be possible to measure downwind air concentrations and utilize them in conjunction with meteorological measurements to back-calculate flux. Therefore, in this paper we propose a back-calculation procedure, which consists of solving for Q in equation 1.

In this paper, we compare flux measurements made in a concurrent study (Majewski et al., 1995) with flux estimates made from the ISCST model using the back-calculation method briefly described above. Use of the model in this manner provides an alternate method for flux estimation and subsequent calculation of buffer zones necessary for the protection of human health.

MATERIALS AND METHODS

Field Plot Preparation

Two commercial lettuce fields, located approximately 16 km east of the city of Monterey, California, were used in this study. One field was 3.9 ha in area and tarped immediately following MeBr application (Figure 1). The other was 6.0 ha and remained untarped after application. Soil of the tarped field is classified as a Salinas Clay Loam (fine-loamy, mixed, thermic Pachic Haploxerolls) with 1.4% organic carbon, 19% sand, 46% silt, and 35% clay. Soil of the untarped field is a Clear Lake Clay (fine montmorillonitic, thermic Typic Pelloxererts) with 2.3% organic carbon, 16% sand, 37% silt, and 47% clay.

Prior to application, the fields were leveled then ripped twice to a depth of approximately 62 cm, disced, and then chiseled twice to a depth of 31 cm. Fumigant application was a mixture of MeBr and chloropicrin (CCl_3NO_2) in a 67%/33% and

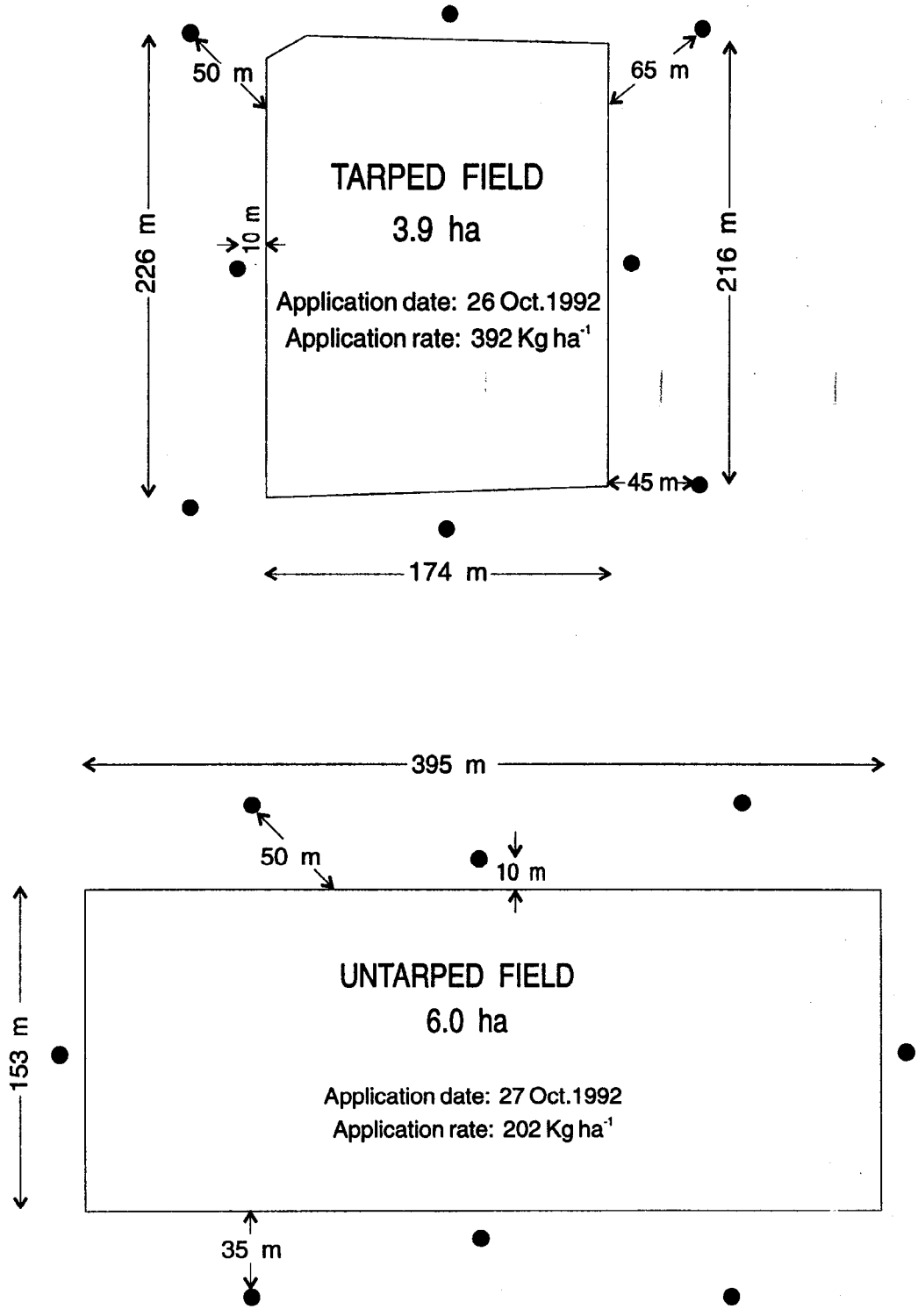

Figure 1. Plot dimensions for the tarped and untarped fields applied with methyl bromide in Monterey County, California. Filled circles (●) represent air sampler locations.

98%/2% ratio on the tarped and untarped fields, respectively. The fumigant mixture was injected at a depth of 25 to 30 cm on both fields at a rate of 392 kg ha^{-1} on October 26, 1992, and 202 kg ha^{-1} on October 27, 1992, on the tarped and untarped fields, respectively. (The amount of MeBr applied was 263 kg ha^{-1} and 198 kg ha^{-1} on the tarped and untarped fields, respectively). On the tarped field, the application and tarping equipment was carried on the same tractor, such that the high-barrier plastic tarp (0.00254 cm thickness) was immediately laid over the injection chisel-line. Edges of the tarps were overlapped and glued to seal the seams. On the untarped field, soil was simply bedded over the fumigant injection line.

Meteorological Data Collection

A meteorological station was placed between 7 and 10 m from the edge of each field. Wind speed and direction were measured with Met-One model 014A and 024A sensors, respectively. Temperature and relative humidity were measured with a Campbell Scientific probe (model 207, Logan, UT). Rainfall was collected at the tarped field only, using a tipping bucket rain gage (model TE525, Campbell Scientific). Meteorological data were compiled and recorded over 15 min intervals using a Campbell Scientific datalogger (Model 21-X).

Air Sampling

MeBr was sampled and trapped using personal air pumps (model 224-PCXR7, SKC West, Fullerton, CA) fitted with glass tubes filled with activated charcoal. Sampling tubes were stacked, two in a series, consisting of a 400 mg primary tube and a 200 mg secondary tube. Flow rates were 45 ml/min during four-hour sampling periods, and 23 ml/min during eight-hour sampling periods so that the total volume of air sampled would not exceed 11 L. Flow rates in excess of 11 L can cause breakthrough of MeBr from the primary to the secondary tube (data not shown). During this study certain air sampling periods exceeded eight hours and therefore total air sampling volumes exceeded 11 L. However, only 2% of all samples collected had breakthrough, as indicated by residues measured in the secondary sampling tubes, suggesting MeBr loss during air sampling was only minor. Flow rates were checked prior to and after each sample collection using a flowmeter (Manostat, NYC, NY) calibrated in the laboratory using a soap film calibrator (model 303, SKC West). After collection, samples were stored on dry ice and kept frozen until analyzed two to three weeks after sample collection.

Eight air samplers were located off-site from each field at a height of approximately 1.2 m (Figure 1). Four of these samplers were located 10 m from the field, 90° apart. Another

four were located about 50 m from the field on a 45° angle offset from the samplers at 10 m. An additional sampler was randomly collocated with one of the above samplers during each sampling period as a check on combined sampling and analytical variability. The relative percent difference between collocated samplers averaged 12%.

Prior to application on each field, two background samples were collected. Both were below the method detection limit of 0.2 μg per sampling tube (about 18 $\mu g\ m^{-3}$). During application, air samplers were run for the duration of the application period which took approximately 5 and 4 hours on the tarped and untarped fields, respectively. Subsequently, air sampling off-site was conducted simultaneously with flux measurements made by Majewski et al. (1995) in a concurrent study. Samples on Day 0 were taken during four-hour intervals, while flux measurements were made every two hours. Air sample changes occurred simultaneously with flux sample changes. Days one to four after application, air samplers were operated for four- and eight-hour intervals, also occurring concurrently with flux sampling periods.

Chemical Analysis

MeBr was extracted from activated charcoal using five to ten ml of nanograde ethyl acetate, vortexing for 30 sec. Three μl

of the extract were injected into a gas chromatograph (Hewlett Packard 5890 II) equipped with an HP-5 column (5% phenyl-methyl polysiloxane, 30 m x 0.54mm i.d. x 2.65 μm) and a Ni^{63} electron capture detector. The carrier gas was He, flow rate 17 ml/min. Injector temperature was 220°C operated in splitless mode, detector temperature 260°C, and temperature program was 50°C initial, held for 2.5 min, with a temperature ramp of 70°C/min, to a final temperature of 210°C held for one min. Spiked samples had an average recovery of 85% (± 3%, n = 6).

In contrast, Majewski et al. (1995) used a headspace gas chromatographic technique to analyze for MeBr, with a detection limit of 0.1 μg per sampling tube. To check for method comparability, 6 replicate (collocated) samples were analyzed in each laboratory. The relative percent difference between results from the two laboratories was 20% and a paired t-test indicated they were not significantly different ($P>0.05$).

Flux Sampling Techniques

The aerodynamic method, conducted by Majewski et al. (1995), was used to measure the volatilization rate of MeBr from the tarped and untarped fields. Briefly, flux samples were collected using a mast located in the center of each field. Air samples and wind speed measurements were taken at 20, 30,

50, 80, 125, and 200 cm above the soil surface. Flux was calculated as the product of concentration and wind gradients, divided by a meteorological stability factor. Sampling techniques and flux measurements can be found in Majewski et al. (1995).

Modeling Techniques and Calculations

Model calculations utilized ISCST version 90346 (Wagner, 1987). Each field was represented as a collection of square subsources which approximated the field shape and area. To estimate σ_y and σ_z, the stability class was assumed to be D (Wark and Warner, 1981) due to the dominance of overcast conditions after fumigant application. Air sampler locations with respect to field geometry were encoded into the model. For each sampling period, concentrations measured at each air sampler were regressed on air concentrations estimated with ISCST using hourly wind speed and direction, and ambient air temperature, and assuming an arbitrary area corrected flux of 100 $\mu g\ m^{-2}\ s^{-1}$. To estimate the actual flux, the regression coefficient was multiplied by 100 $\mu g\ m^{-2}\ s^{-1}$. Flux measurements made during each sampling period by Majewski et al. (1995), and corresponding back-calculated flux estimates, were each aggregated into daily (ca. 24 hour), time weighted averages. Daily time weighted averages of measured flux and back-calculated flux were then compared using regression analysis.

RESULTS AND DISCUSSION

Meteorological Conditions

During application of MeBr on the tarped field, temperatures ranged from 16 to 24°C, and wind speeds averaged 2.9 m s^{-1} (Appendix I). During application on the untarped field, temperatures were similar (16 to 20°C), and winds averaged 2.1 m s^{-1}. Subsequently, afternoon highs on both fields averaged 20°C, nightly lows averaged 12°C, and wind speeds ranged from calm (<1.0 m s^{-1}) to 9.4 m s^{-1}. On 28 and 29 October, a light rain fell during daylight hours and on 30 and 31 October, heavier rains fell totaling about 8.5 mm.

Air Concentrations

Air concentrations measured off-site during application ranged from 15.1 to 190 $\mu g\ m^{-3}$ and from none detected to 590 $\mu g\ m^{-3}$ on the tarped and untarped fields, respectively (Table 1). Maximum concentrations occurred five hours after application on the tarped field, and immediately following application on the untarped field. Highest measured concentrations were 2000 and 2900 $\mu g\ m^{-3}$ for the tarped and untarped fields, respectively. All air concentrations can be found in Appendices II and III.

Air concentrations generally declined over time on both fields yet concentrations declined more slowly on the tarped than the

Table 1. Range in Methyl Bromide Concentrations Measured at 10 and 50m From the Tarped and Untarped Fields.

Tarped					Untarped				
Day[a]	Hour[b]	Duration (Hours)[c]	Distance (m)	Range ($\mu g\ m^{-3}$)	Day[a]	Hour[b]	Duration (Hours)[c]	Distance (m)	Range ($\mu g\ m^{-3}$)
During Application	0820	5.4	10	100 - 190	During Application	1000	3.9	10	46 - 590
			50	15 - 140				50	ND - 420
0	1400	4.6	10	ND[d] - 680	0	1400	4.6	10	ND - 2900
			50	ND - 460				50	ND - 1800
	1830	4.2	10	ND - 2000		1840	4.4	10	ND - 3000
			50	ND - 890				50	ND - 2400
	2300	4.5	10	140 - 1100		2300	4.5	10	ND - 1600
			50	ND - 770				50	ND - 1400
	0300	4.6	10	150 - 910		0330	4.75	10	ND - 360
			50	ND - 210				50	ND - 220
	0800	5.1	10	48 - 240		0815	4.5	10	ND - 290
			50	16 - 77				50	ND - 200
1	1300	4.0	10	ND - 340	1	1245	3.8	10	ND - 260
			50	ND - 250				50	ND - 200
	1700	4.0	10	ND - 660		1630	4.4	10	ND - 660
			50	ND - 190				50	ND - 200
	2130	8.6	10	ND - 400		2100	8.7	10	31 - 480
			50	ND - 320				50	41 - 310
	0600	4.7	10	ND - 360		0545	4.2	10	ND - 130
			50	ND - 120				50	ND - 100
2	1300	8.7	10	ND - 190	2	1200	8.5	10	47 - 91
			50	ND - 120				50	18 - 140
	2145	8.7	10	43 - 190		2030	9.0	10	55 - 280
			50	50 - 280				50	39 - 190
	0630	4.0	10	ND - 74		0530	4.0	10	ND - 83
			50	ND - 53				50	ND - 46
3	1245	8.9	10	54 - 94	3	1210	8.5	10	ND - 120
			50	24 - 57				50	ND - 130
	2145	8.6	10	28 - 170		2040	8.9	10	20 - 190
			50	38 - 150				50	ND - 190
	0615	3.9	10	ND - 130		0530	4.2	10	ND - 76
			50	ND - 89				50	ND - 61
4	1300	8.8	10	ND - 180	4	1225	8.4	10	ND - 49
			50	ND - 95				50	28 - 59
	2145	8.7	10	ND - 140		2050	8.9	10	64 - 100
			50	ND - 160				50	47 - 75
	0630	4.1	10	ND - 87		0550	4.2	10	ND - 19
			50	ND - 68				50	ND - 11

a. Day post-application. Day 0 is the day of application.
b. Approximate time air sampling began.
c. Duration of air sampling period.
d. None detected. Detection limits are 0.2 μg per sampling tube, about 18 $\mu g\ m^{-3}$.

untarped field (Table 1). By Day 4, concentrations around the tarped field were higher than those around the untarped field. Use of a high barrier tarp apparently slows the loss of MeBr from a field, yet prolongs emission of the fumigant.

Differential concentrations measured off-site from the tarped and untarped fields were related to the difference in flux rates (Majewski et al., 1995, Appendix IV) and to wind patterns. Flux rates measured immediately following application on the tarped field were approximately half those on the untarped field, even though the tarped field had a slightly higher application rate. In part, lower flux of MeBr from the tarped field led to lower off-site concentrations than those found for the untarped field. Abdalla et al. (1974) showed that MeBr concentrations in the soil atmosphere are three times higher in tarped *vs.* untarped fields. Under tarped conditions, more MeBr remains in soil initially and less escapes to the atmosphere, than under untarped conditions. In contrast, flux measurements made four to five days after application were the reverse, higher on the tarped than the untarped field (Majewski et al., 1995, Appendix IV). This too, helps explain differential air concentrations measured off-site from the fields.

In addition to differential flux rates accounting for different off-site concentrations, wind patterns were also a

factor. For example, on day 0, wind direction was more variable on the tarped than on the untarped field, contributing to the lower concentrations measured off-site in any one direction on the tarped field (Table 1 and Appendix I).

Air concentrations taken over a four or eight hour period are important from a worker exposure and acute toxicity perspective. In addition, the calculation of a 24-hour exposure is important for protection of the local population from acute MeBr exposure. The 24-hour targeted concentration around fields treated with MeBr is 815 ug m^{-3} (Nelson, 1992). Time-weighted daily averages around the tarped field were all below this level, yet were exceeded on the untarped field at the 10 and 50 m distance (Figures 2 and 3). In this instance, a modeling approach could be used to establish the appropriate buffer zone for the protection of individuals residing near untarped fumigations.

Wind-Rose Diagrams

To develop a graphical overview of off-site air concentrations in relation to meteorological conditions, daily wind-rose diagrams were developed (Figures 2 and 3). These diagrams also contain air concentrations, depicted in their actual sampling locations, averaged over a 24-hour period. The daily

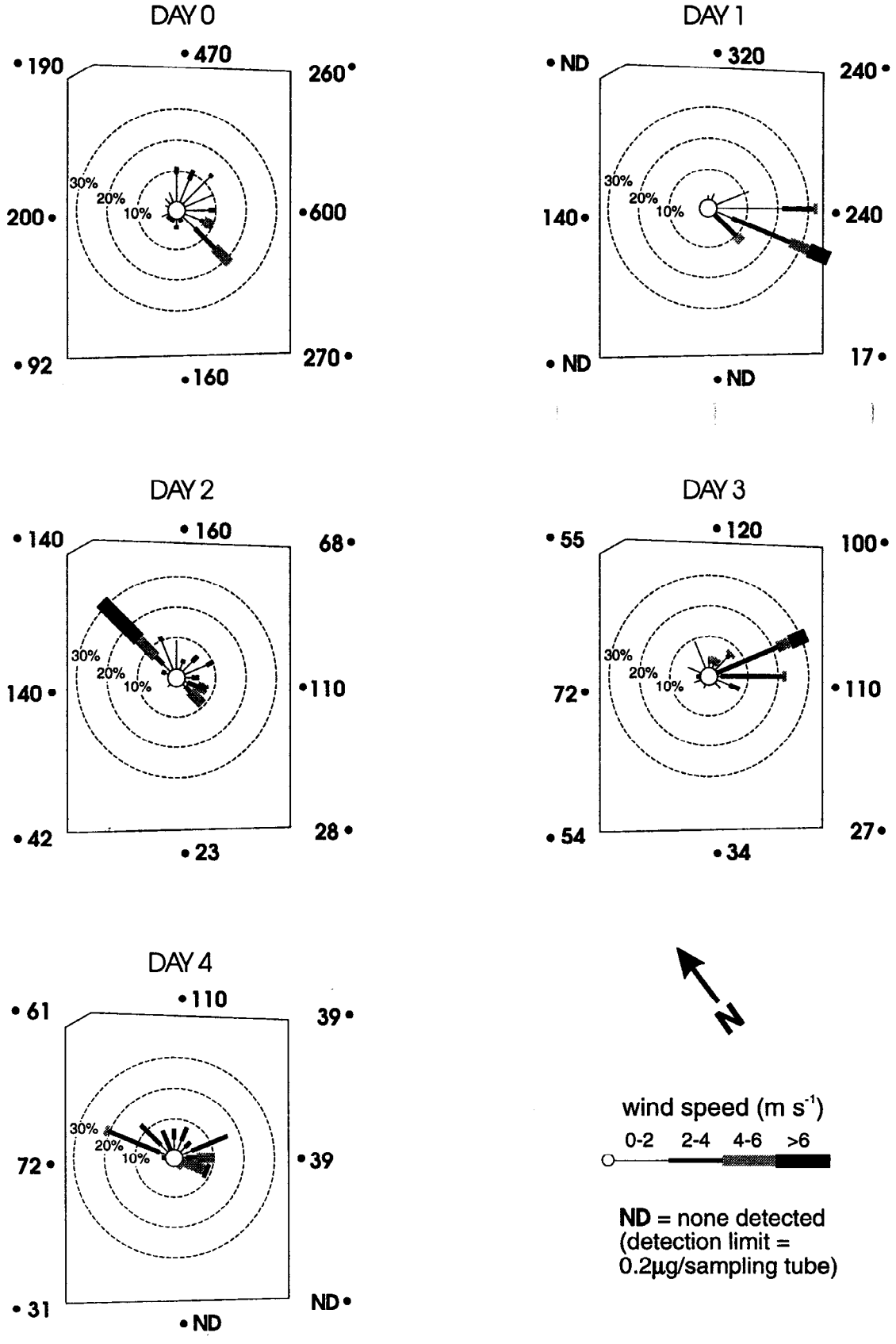

Figure 2. Stylized wind-rose diagrams and methyl bromide concentrations (µg m^{-3}) around the tarped field 0-4 days after application. The wind-rose diagram is a frequency distribution of wind direction and speed (see text for explanation).

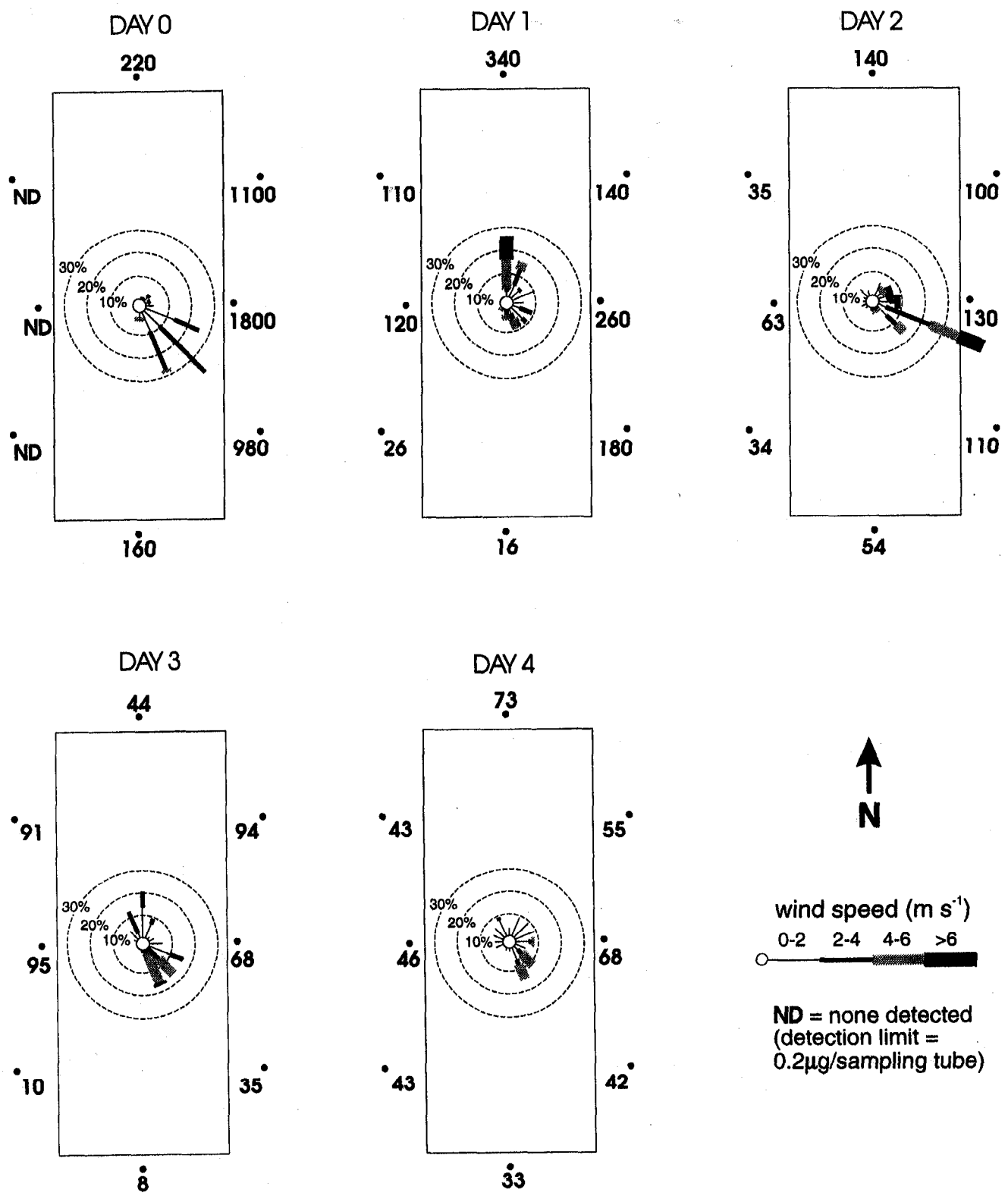

Figure 3. Stylized wind-rose diagrams and methyl bromide concentrations (µg m^{-3}) around the untarped field 0-4 days after application. The wind-rose diagram is a frequency distribution of wind direction and speed (see text for explanation).

wind-rose diagram is a frequency distribution of wind direction and speed (Wark and Warner, 1981) measured during a 24-hour period. Wind-rose diagrams typically consist of spokes showing the direction from which the wind is coming. However, to facilitate interpretation of the relationship between wind direction and MeBr concentrations, spokes point in the direction the wind is blowing. Spoke length is equivalent to the duration of time the wind blew in that direction and spoke width represents wind speed. Atmospheric dispersion from a source is related to wind direction, duration, and speed, proximity to the source, and atmospheric stability (Zannetti, 1990). Samplers downwind of an area source for the longest period of time, under slow to moderate wind speeds (which minimize dilution), closest to the source, and under stable atmospheric conditions, are expected to have the highest concentrations. Therefore, in Figures 2 and 3, samplers downwind of the longest spokes which are relatively narrow, (i.e. samplers located directly downwind, for the longest period of time, under slow to moderate wind speeds), are expected to have the highest concentrations.

In general, air samplers downwind of each field have higher concentrations than those upwind (Figures 2 and 3). To explore the relationship between MeBr concentrations, day post-application, wind parameters and air sampler distance from each field, a Pearson correlation analysis was conducted

(Sokal and Rohlf, 1973). MeBr concentrations measured off-site from both fields were inversely correlated with day post-application ($P \leq 0.05$) indicating dissipation and/or degradation occurred on each field during the five day study. Flux measurements made by Majewski et al. (1995, Appendix IV) in their concurrent study confirmed the decline in emission rates over time. In addition, wind patterns generally matched MeBr concentrations detected off-site as indicated by the wind-rose diagrams (Figures 2 and 3). Wind direction was significantly correlated with MeBr concentration ($P \leq 0.10$). In contrast, distance from the treated field and wind speed were not significantly correlated with concentration ($P > 0.10$). Lack of correlation between concentrations and distance to each sampler could be due to inability of the statistical analysis to take into account variation in wind direction and its effect on the distance to each sampler. The lack of correlation between concentrations and wind speed could be related to the close proximity of samplers to the field where dilution effects due to high wind speeds may be minimal. Time averaging over a 24-hour period can also obscure these relationships in addition to the lack of information about atmospheric stability, which was not measured directly in this study.

Modeled Predictions of Flux

For both the tarped and untarped fields, the relationship between measured and predicted 24-hour flux was significant ($P < 0.01$), with coefficients of 1.36 and 2.04, respectively (Figure 4). Perfect flux prediction would have resulted in a coefficient of 1.0. Though the model underpredicted flux, the coefficient for the tarped field was not significantly different from 1.0 (95% confidence interval: 0.62-2.1). For the untarped field the coefficient was significantly different from 1.0 (95% confidence interval: 1.3-2.8). For both fields, the intercepts were not significantly different from 0 ($P > 0.05$).

The tendency to underpredict flux resulted, in part, from the tendency of the ISCST model to overestimate downwind air concentrations by 13% (Petersen, 1992). Adjusting for this discrepancy would result in multiplicative coefficients of 1.20 and 1.81 for tarped and untarped fields, respectively. However, the slope from untarped data remains significantly different from 1.0, which suggests other mechanisms at work.

Another explanation is the nature of the algorithm in ISCST. For most area sources, it is necessary to divide the area into a number of square subsources. The model then takes each square subsource and calculates the diameter for a circle

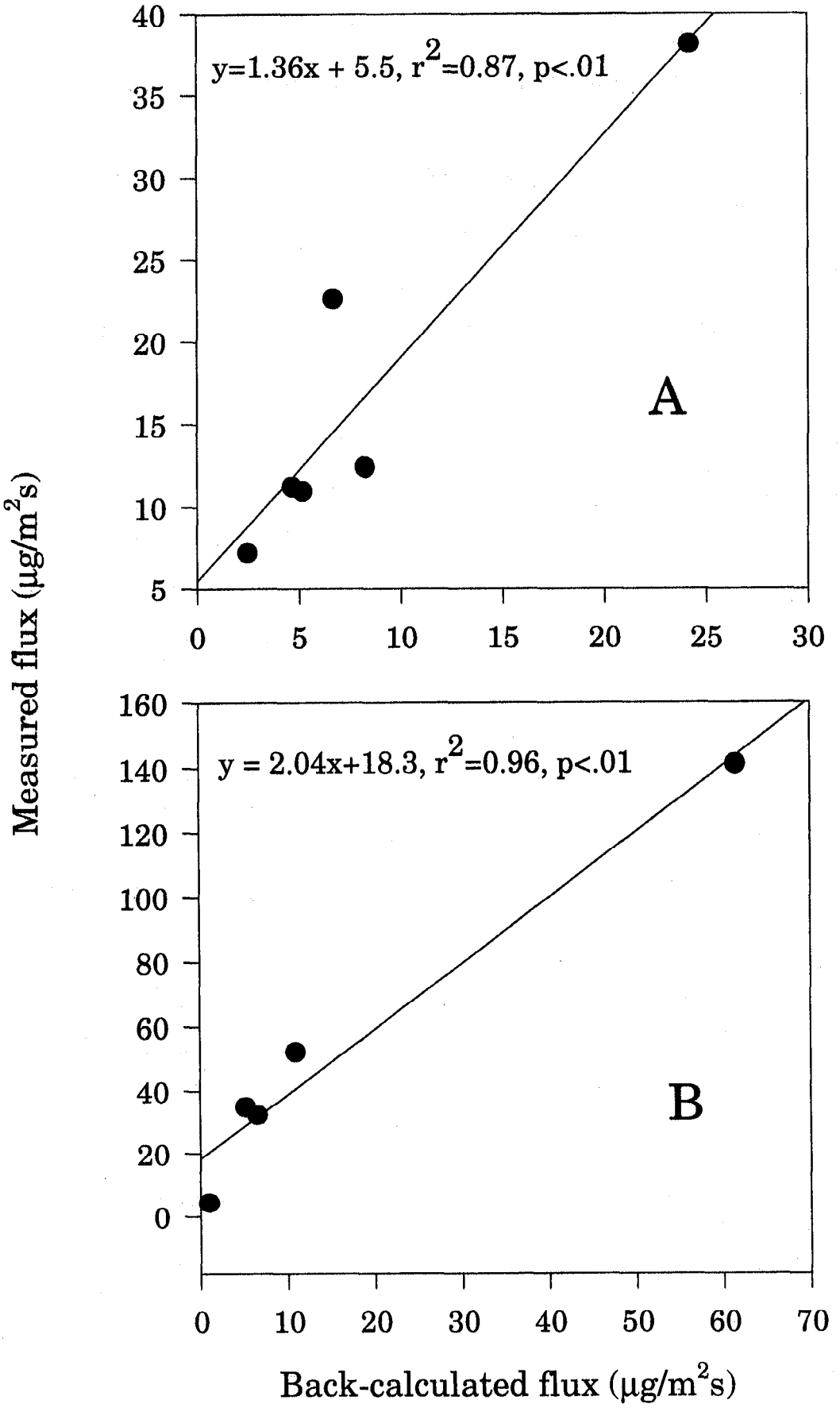

Figure 4. Measured versus back-calculated flux values for (A) tarped and (B) untarped fields.

equivalent in area. Downwind air concentrations are then calculated using the diameter of the circle as a line source, oriented perpendicular to the wind, and placed at the upwind edge of the circle (Figure 5). With more then one subsource, the endpoints of these line segments may overlap, doubling the source strength, resulting in locally higher air concentrations (Figure 5). Under variable wind conditions, these effects merge, but have their greatest effect near the source. This too was indicated by the insignificant correlation between wind speed, distance, and downwind air concentrations.

Another reason the model may have overpredicted air concentrations is our use of D stability class throughout the entire study. When period 2 of the untarped field is run with a fixed flux rate at D and subsequently at C stability, the estimated air concentrations are reduced by 38%. For both fields, the largest flux during the initial 1-2 days dominated the comparative regressions. There may have been stability conditions other than D during the first 2 days, where cloud cover was not as pervasive as in later sampling periods. Since selection of stability class can affect model results, future work should attempt to measure or accurately estimate an average stability for each sampling period.

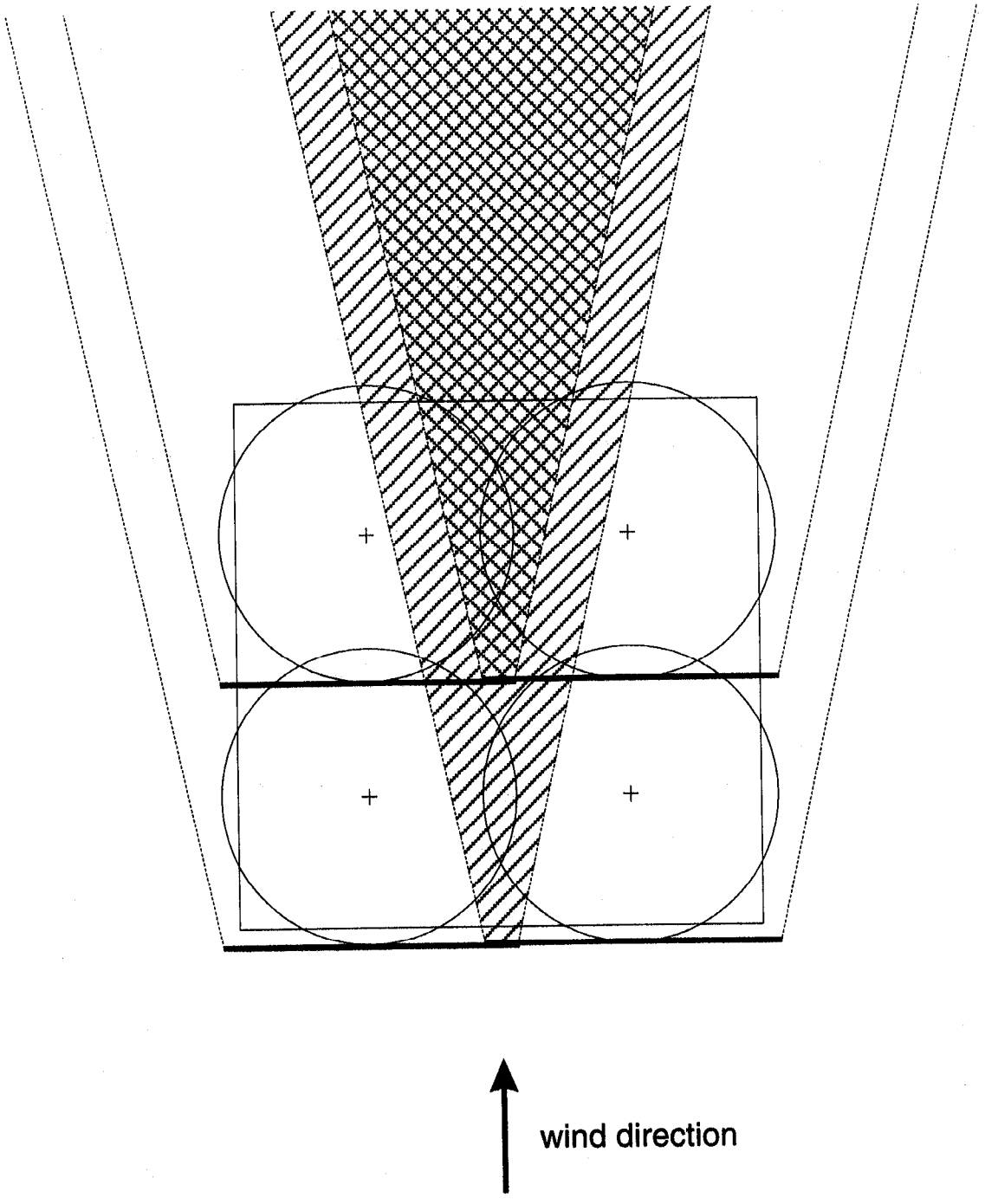

Figure 5. Stylized diagram with field divided into 4 subsources duplicated in area by 4 circles. The line segment corresponding to the diameter of the circle (bold Lines) is moved to the windward edge of the circle, perpendicular to the wind. Locally doubled air concentrations are represented in the figure as single and cross hatched areas. Dotted lines indicate the 'edge' of the plume from each subsource. Actual angles of the plume 'edge' will depend on atmospheric stability. The magnitude of air-concentration doubling is diminished farther downwind and with greater variability in wind direction.

CONCLUSIONS

Maximum concentrations around the tarped field were generally lower than around the untarped field during application and up to 1 day after application. Air concentrations generally declined over time on both fields yet concentrations declined more slowly on the tarped than the untarped field. High barrier tarps apparently slow the release of MeBr from field fumigations (Abdalla, et al., 1974), yet prolong emission of the fumigant (Majewski et al., 1995). In addition, the targeted concentration of 815 ug m^{-3} was not exceeded on the tarped field. However, this value was exceeded around the untarped field, indicating the need to use a modeling approach to establish a protective buffer zone around fields treated with MeBr in this manner.

Correlation analyses confirmed a decline in MeBr concentrations over the 5-day sampling period and a relationship between wind direction and off-site concentrations. In contrast, distance from the treated field was not significantly correlated with concentrations. This lack of correlation could be due to a number of factors including the inability of the statistical analysis to take into account the variation in wind direction and its effect on the distance to each sampler. The model, however, takes this and other interactive effects into account since it simultaneously

estimates the effects of wind direction and speed, atmospheric stability, and distance from the source (equation 1).

When compared to measured flux rates, back-calculated rates using ISCST were systematically lower because the model overestimates off-site air concentrations. Although flux rates will be systematically underestimated, off-site air concentrations will be closely approximated since the model proportionally overestimates off-site air concentrations. These offsetting effects imply that the judicious use of 24-hour average, back-calculated flux values should provide a reasonable basis for establishing buffer zones.

The back-calculation method appears to be a viable procedure for estimating flux and should be tested under different conditions with different pesticides. In addition, its use in estimating buffer zones should be further investigated by verifying that buffer zones are in fact within model predictions of downwind air concentrations.

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	Appendix 1. Meteorological data summarized from the tarped and untarped fields treated with methyl bromide.													
Hours	Tarped Field							Untarped Field						
After		Sampling	Time Period		Average	Wind	Wind		Sampling	Time Period		Average	Wind	Wind
Application	Day[a]	Period	Began	Ended	Temp(K)	Direction[b]	Speed(m/s	Day	Period	Began	Ended	Temp(K)	Direction[b]	Speed(m/s
0	c	1	9:01	10:00	291	307	3.7							
0	c	1	10:01	11:00	293	298	2.3	c	1	10:15	11:00	290	32	<1
0	c	1	11:01	12:00	296	288	1.6	c	1	11:15	12:00	292	10	1.1
0	c	1	12:01	13:00	297	106	1.7	c	1	12:15	13:00	292	137	1.9
0	c	1	13:01	14:00	296	147	5.0	c	1	13:15	14:00	290	139	2.6
1	0	2	14:01	15:00	294	144	5.4	0	2	14:15	15:00	290	129	3.1
2	0	2	15:01	16:00	292	150	4.2	0	2	15:15	16:00	289	124	2.7
3	0	2	16:01	17:00	293	146	2.4	0	2	16:15	17:00	289	124	2.2
4	0	2	17:01	18:00	292	164	2.5	0	2	17:15	18:00	289	131	1.8
5	0	2[d]	18:01	19:00	290	79	1.2	0	2[d]	18:15	19:00	289	147	1.4
6	0	3	19:01	20:00	290	132	0.5	0	3	19:15	20:00	289	147	1.1
7	0	3	20:01	21:00	289	118	0.6	0	3	20:15	21:00	289	124	1.2
8	0	3	21:01	22:00	288	141	1.2	0	3	21:15	22:00	289	132	2.4
9	0	3[d]	22:01	23:00	288	217	2.2	0	3	22:15	23:00	288	114	2.3
10	0	4	23:01	0:00	288	99	1.0	0	4	23:15	0:00	288	112	2.5
11	0	4	0:01	1:00	287	1	0.6	0	4	0:15	1:00	288	103	2.2
12	0	4	1:01	2:00	287	10	1.3	0	4	1:15	2:00	288	109	2.2
13	0	4	2:01	3:00	287	39	0.9	0	4	2:15	3:00	288	112	1.7
14	0	4[d]	3:01	4:00	287	89	1.0	0	4[d]	3:15	4:00	288	100	1.4
15	0	5	4:01	5:00	287	86	1.5	0	5	4:15	5:00	288	121	2.1
16	0	5	5:01	6:00	288	86	1.6	0	5	5:15	6:00	288	101	2.0
17	0	5	6:01	7:00	288	57	1.6	0	5	6:15	7:00	288	97	1.5
18	0	5	7:01	8:00	288	37	2.0	0	5	7:15	8:00	288	44	1.2
19	0	6	8:01	9:00	289	73	1.3	0	5[d]	8:15	9:00	289	98	1.2
20	0	6	9:01	10:00	289	94	1.0	0	6	9:15	10:00	289	141	3.4
21	0	6	10:01	11:00	290	322	0.2	0	6	10:15	11:00	289	140	3.3
22	0	6	11:01	12:00	293	12	1.2	0	6	11:15	12:00	290	64	1.4
23	0	6	12:01	13:00	293	139	3.3	0	6	12:15	13:00	290	136	2.9
24	1	7	13:01	14:00	292	139	5.1	1	7	13:15	14:00	289	140	4.0
25	1	7	14:01	15:00	291	129	6.2	1	7	14:15	15:00	289	144	4.8
26	1	7	15:01	16:00	290	124	5.9	1	7	15:15	16:00	288	137	3.5
27	1	7	16:01	17:00	289	124	4.3	1	7[d]	16:15	17:00	288	107	2.3
28	1	8	17:01	18:00	289	131	3.4	1	8	17:15	18:00	288	67	1.5
29	1	8	18:01	19:00	289	147	3.0	1	8	18:15	19:00	288	46	1.5

Hours	Tarped Field							Untarped Field						
After		Sampling	Time Period		Average	Wind	Wind		Sampling	Time Period		Average	Wind	Wind
Application	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s
30	1	8	19:01	20:00	289	147	2.4	1	8	19:15	20:00	288	26	1.8
31	1	8	20:01	21:00	289	125	2.0	1	8	20:15	21:00	287	103	1.5
32	1	8[d]	21:01	22:00	289	132	2.4	1	9	21:15	22:00	287	82	1.4
33	1	9	22:01	23:00	288	114	2.3	1	9	22:15	23:00	287	127	1.4
34	1	9	23:01	0:00	288	112	2.5	1	9	23:15	0:00	287	81	0.9
35	1	9	0:01	1:00	288	104	1.6	1	9	0:15	1:00	287	47	0.9
36	1	9	1:01	2:00	288	109	1.8	1	9	1:15	2:00	287	358	1.8
37	1	9	2:01	3:00	288	111	1.8	1	9	2:15	3:00	286	10	1.9
38	1	9	3:01	4:00	288	99	1.5	1	9	3:15	4:00	287	3	2.9
39	1	9	4:01	5:00	288	123	1.6	1	9	4:15	5:00	286	355	4.3
40	1	9	5:01	6:00	288	103	1.4	1	9	5:15	6:00	286	354	4.6
41	1	10	6:01	7:00	288	96	1.2	1	10	6:15	7:00	287	349	6.2
42	1	10	7:01	8:00	288	45	1.3	1	10	7:15	8:00	288	353	5.8
43	1	10	8:01	9:00	289	96	1.1	1	10	8:15	9:00	289	348	6.8
44	1	10	9:01	10:00	289	142	2.8	1	10	9:15	10:00	289	354	6.2
45	1	10	10:01	11:00	289	140	3.6	1	10	10:15	11:00	291	24	5.5
46	-1	e	11:01	12:00	290	99	1.2	1	10	11:15	12:00	293	51	6.5
47	-1	e	12:01	13:00	291	144	2.8	2	11	12:15	13:00	292	42	5.4
48	2	11	13:01	14:00	290	140	4.5	2	11	13:15	14:00	292	77	8.2
49	2	11	14:01	15:00	290	149	4.3	2	11	14:15	15:00	292	96	7.2
50	2	11	15:01	16:00	288	143	4.2	2	11	15:15	16:00	292	97	6.9
51	2	11	16:01	17:00	288	90	2.0	2	11	16:15	17:00	291	116	5.3
52	2	11	17:01	18:00	288	67	1.6	2	11	17:15	18:00	290	117	2.2
53	2	11	18:01	19:00	288	68	1.8	2	11	18:15	19:00	289	240	0.4
54	2	11	19:01	20:00	288	49	1.4	2	11	19:15	20:00	289	329	0.5
55	2	11	20:01	21:00	287	91	1.9	2	11[d]	20:15	21:00	289	20	0.7
56	2	11[d]	21:01	22:00	287	57	0.4	2	12	21:15	22:00	289	104	1.5
57	2	12	22:01	23:00	287	127	0.9	2	12	22:15	23:00	288	18	0.9
58	2	12	23:01	0:00	287	347	0.8	2	12	23:15	0:00	288	23	1.2
59	2	12	0:01	1:00	286	7	1.4	2	12	0:15	1:00	288	252	0.4
60	2	12	1:01	2:00	286	11	1.5	2	12	1:15	2:00	289	84	1.9
61	2	12	2:01	3:00	286	8	1.4	2	12	2:15	3:00	290	86	3.7
62	2	12	3:01	4:00	286	352	1.8	2	12	3:15	4:00	290	95	4.7
63	2	12	4:01	5:00	286	327	3.2	2	12	4:15	5:00	290	91	4.2
64	2	12	5:01	6:00	286	328	4.8	2	12[d]	5:15	6:00	289	101	2.1

Hours	Tarped Field							Untarped Field						
After		Sampling	Time Period		Average	Wind	Wind		Sampling	Time Period		Average	Wind	Wind
Application	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s
65	2	12[d]	6:01	7:00	287	338	6.1	2	13	6:15	7:00	290	104	4.0
66	2	13	7:01	8:00	288	333	5.9	2	13	7:15	8:00	290	106	4.3
67	2	13	8:01	9:00	289	335	6.9	2	13	8:15	9:00	291	100	3.4
68	2	13	9:01	10:00	289	338	7.1	2	13	9:15	10:00	291	102	3.4
69	2	13[d]	10:01	11:00	291	340	6.9	2	13	10:15	11:00	291	134	3.2
70	3	14	11:01	12:00	292	3	3.9	2	13	11:15	12:00	290	126	5.1
71	3	14	12:01	13:00	292	15	4.4	3	14	12:15	13:00	291	133	5.2
72	3	14	13:01	14:00	293	65	5.4	4	14	13:15	14:00	290	140	5.4
73	3	14	14:01	15:00	293	92	6.1	4	14	14:15	15:00	291	128	4.8
74	3	14	15:01	16:00	292	91	5.5	4	14	15:15	16:00	291	132	4.9
75	3	14	16:01	17:00	292	115	3.7	4	14	16:15	17:00	290	122	4.3
76	3	14	17:01	18:00	291	109	2.0	4	14	17:15	18:00	289	110	3.1
77	3	14	18:01	19:00	290	87	1.5	4	14	18:15	19:00	288	97	1.9
78	3	14	19:01	20:00	290	317	0.8	4	14	19:15	20:00	287	84	1.6
79	3	14	20:01	21:00	290	286	1.7	4	15	20:15	21:00	286	98	1.8
80	3	14	21:01	22:00	289	133	0.8	4	15	21:15	22:00	286	61	1.3
81	3	15	22:01	23:00	289	357	0.7	4	15	22:15	23:00	286	60	1.0
82	3	15	23:01	0:00	289	18	0.7	4	15	23:15	0:00	285	312	0.8
83	3	15	0:01	1:00	289	64	1.2	4	15	0:15	1:00	285	317	1.6
84	3	15	1:01	2:00	289	85	1.6	4	15	1:15	2:00	284	350	1.4
85	3	15	2:01	3:00	289	93	2.4	4	15	2:15	3:00	283	3	1.4
86	3	15	3:01	4:00	289	100	2.9	4	15	3:15	4:00	282	339	1.5
87	3	15	4:01	5:00	290	81	2.2	4	15	4:15	5:00	282	348	1.6
88	3	15	5:01	6:00	290	96	2.9	4	15[d]	5:15	6:00	282	332	2.2
89	3	15[d]	6:01	7:00	289	80	1.6	4	16	6:15	7:00	282	343	2.0
90	3	16	7:01	8:00	290	98	2.9	4	16	7:15	8:00	284	345	1.9
91	3	16	8:01	9:00	290	88	2.5	4	16	8:15	9:00	286	328	3.2
92	3	16	9:01	10:00	291	101	2.6	4	16	9:15	10:00	288	332	3.3
93	3	16[d]	10:01	11:00	291	103	2.4	4	16	10:15	11:00	290	318	2.1
94	-1	d	11:01	12:00	291	123	4.5	4	16	11:15	12:00	292	286	1.7
95	-1	d	12:01	13:00	290	129	5.5	4	16[d]	12:15	13:00	294	48	1.6
96	4	17	13:01	14:00	289	137	5.7	5	17	13:15	14:00	293	143	4.7
97	4	17	14:01	15:00	290	118	4.3	5	17	14:15	15:00	293	135	4.7
98	4	17	15:01	16:00	291	124	4.6	5	17	15:15	16:00	293	126	4.3
99	4	17	16:01	17:00	290	125	3.9	5	17	16:15	17:00	291	128	3.6

Hours	Tarped Field							Untarped Field						
After		Sampling	Time Period		Average	Wind	Wind		Sampling	Time Period		Average	Wind	Wind
Application	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s	Day	Period	Began	Ended	Temp(K)	Direction	Speed(m/s
100	4	17	17:01	18:00	288	96	1.5	5	17	17:15	18:00	290	128	1.7
101	4	17	18:01	19:00	287	83	2.3	5	17	18:15	19:00	288	29	0.4
102	4	17	19:01	20:00	286	82	2.3	5	17	19:15	20:00	287	55	0.5
103	4	17	20:01	21:00	286	77	2.4	5	17[d]	20:15	21:00	286	11	0.7
104	4	17	21:01	22:00	286	49	2.0	5	18	21:15	22:00	286	4	0.8
105	4	18	22:01	23:00	286	39	1.8	5	18	22:15	23:00	285	224	0.5
106	4	18	23:01	0:00	286	52	2.0	5	18	23:15	0:00	285	31	0.9
107	4	18	0:01	1:00	285	1	2.5	5	18	0:15	1:00	284	43	0.6
108	4	18	1:01	2:00	285	3	2.7	5	18	1:15	2:00	284	258	0.8
109	4	18	2:01	3:00	284	355	1.8	5	18	2:15	3:00	285	8	0.7
110	4	18	3:01	4:00	282	325	2.1	5	18	3:15	4:00	284	310	1.2
111	4	18	4:01	5:00	282	319	2.2	5	18	4:15	5:00	284	31	0.4
112	4	18	5:01	6:00	282	322	2.3	5	18	5:15	6:00	285	339	0.2
113	4	18[d]	6:01	7:00	281	326	2.2	5	19	6:15	7:00	284	339	0.2
114	4	19	7:01	8:00	283	315	2.2	5	19	7:15	8:00	286	7	0.9
115	4	19	8:01	9:00	285	312	3.4	5	19	8:15	9:00	287	72	0.6
116	4	19	9:01	10:00	287	320	3.9	5	19	9:15	10:00	289	306	1.7
117	4	19[d]	10:01	11:00	290	312	2.7							

a. Day after application. Day 0 = day of application. Application date for the tarped field was Oct. 26, and the untarped field Oct. 27, 1992.

b. Vector averaged wind direction. Wind direction from the untarped field was lost from 0 to 25 hours after application. Wind direction data from the tarped field was vector averaged with wind speeds from the untarped field during that period.

c. During application.

d. Hourly meteorological data was split between two air sampling periods when used in model calculations.

e. Air sampling did not occur during these hours.

Appendix II. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Tarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
0	-1	0	0	B[d]	10/26/92	13 26	44.5	240	4.00	10.7	ND[e]	ND	ND	
0	-1	0	0	B	10/26/92	13 10	46.5	240	4.00	11.2	ND	ND	ND	
1	0	1	1		10/26/92	08 29	45.6	327	5.45	14.9	2.19	147	37.8	
1	0	1	2		10/26/92	08 26	42.3	324	5.40	13.7	1.94	142	36.5	
1	0	1	3		10/26/92	08 24	44.8	322	5.37	14.4	2.26	157	40.4	
1	0	1	4		10/26/92	08 21	41.5	319	5.32	13.2	0.2	15.1	3.89	
1	0	1	5		10/26/92	08 18	44.4	316	5.27	14.0	2.61	186	47.9	1
1	0	1	6		10/26/92	08 16	41.9	310	5.17	13.0	1.32	102	26.2	
1	0	1	7		10/26/92	08 33	42.6	332	5.53	14.1	1.37	96.9	25.0	
1	0	1	7	R[f]	10/26/92	08 33	43.4	332	5.53	14.4	1.63	113	29.1	
1	0	1	8		10/26/92	08 31	43.4	329	5.48	14.3	1.02	71.4	18.4	
2	0	2	1		10/26/92	13 56	46.2	261	4.35	12.1	8.22	682	176	
2	0	2	2		10/26/92	13 59	42.6	267	4.45	11.4	2.98	262	67.5	
2	0	2	3		10/26/92	14 02	44.1	269	4.48	11.9	0.82	69.1	17.8	
2	0	2	4		10/26/92	14 07	42.3	270	4.50	11.4	ND	ND	ND	
2	0	2	5		10/26/92	14 10	44.4	271	4.52	12.0	ND	ND	ND	
2	0	2	6		10/26/92	14 13	42.6	273	4.55	11.6	ND	ND	ND	
2	0	2	7		10/26/92	14 12	48.1	283	4.72	13.6	1.29	94.8	24.4	
2	0	2	8		10/26/92	14 02	45.2	298	4.97	13.5	6.14	456	117	
3	0	3	1		10/26/92	18 18	46.2	255	4.25	11.8	18.8	1596	411	
3	0	3	1	R	10/26/92	18 18	39.7	255	4.25	10.1	19.9	1966	506	
3	0	3	2		10/26/92	18 27	41.9	255	4.25	10.7	7.49	701	181	
3	0	3	3		10/26/92	18 33	45.2	253	4.22	11.4	1.41	123	31.8	
3	0	3	4		10/26/92	18 38	41.9	253	4.22	10.6	ND	ND	ND	
3	0	3	5		10/26/92	18 42	42.6	254	4.23	10.8	ND	ND	ND	
3	0	3	6		10/26/92	18 48	42.2	252	4.20	10.6	ND	ND	ND	
3	0	3	7		10/26/92	18 58	47.4	158	2.63	7.5	2.55	340	87.7	2
3	0	3	8		10/26/92	19 01	44.4	249	4.15	11.1	9.79	886	228	
4	0	4	1		10/26/92	22 37	45.9	269	4.48	12.3	2.73	221	57.0	
4	0	4	2		10/26/92	22 43	41.2	269	4.48	11.1	1.38	125	32.1	
4	0	4	3		10/26/92	22 47	44.4	266	4.43	11.8	13.1	1109	286	
4	0	4	4		10/26/92	22 52	45.5	271	4.52	12.3	9.54	774	199	
4	0	4	5		10/26/92	22 57	43.4	270	4.50	11.7	9.17	783	202	
4	0	4	6		10/26/92	23 01	43.4	271	4.52	11.8	5.21	443	114	
4	0	4	7		10/26/92	23 06	44.4	270	4.50	12.0	1.65	138	35.5	
4	0	4	8		10/26/92	23 15	43	267	4.45	11.5	ND	ND	ND	
4	0	4	8	R	10/26/92	23 12	43.7	269	4.48	11.8	ND	ND	ND	
5	1	1	1		10/27/92	03 09	45.9	272	4.53	12.5	3.72	298	76.8	
5	1	1	2		10/27/92	03 13	41.9	276	4.60	11.6	2.43	210	54.1	
5	1	1	3		10/27/92	03 17	45.6	280	4.67	12.8	8.76	686	177	

Appendix II. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Tarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
5	1	1	3	R	10/27/92	03 19	45.2	279	4.65	12.6	11.5	912	235	
5	1	1	4		10/27/92	03 24	44.8	280	4.67	12.5	1.92	153	39.4	
5	1	1	5		10/27/92	03 29	45.2	279	4.65	12.6	1.85	147	37.8	
5	1	1	6		10/27/92	03 33	44.8	279	4.65	12.5	ND	ND	ND	
5	1	1	7		10/27/92	03 36	42.6	280	4.67	11.9	2.21	185	47.7	
5	1	1	8		10/27/92	03 43	43.7	277	4.62	12.1	ND	ND	ND	
6	1	2	1		10/27/92	07 44	45.2	306	5.10	13.8	2.84	205	52.9	1
6	1	2	2		10/27/92	07 52	42.6	304	5.07	13.0	0.63	48.6	12.5	
6	1	2	3		10/27/92	08 00	43.7	301	5.02	13.2	2.92	222	57.2	1
6	1	2	3	R	10/27/92	08 00	43.7	304	5.07	13.3	3.21	242	62.3	1
6	1	2	4		10/27/92	08 05	44.4	307	5.12	13.6	0.28	20.5	5.29	
6	1	2	5		10/27/92	08 09	45.2	309	5.15	14.0	0.67	48.0	12.4	
6	1	2	6		10/27/92	08 13	44.4	310	5.17	13.8	0.22	16.0	4.12	
6	1	2	7		10/27/92	08 17	45.6	311	5.18	14.2	1.15	81.1	20.9	
6	1	2	8		10/27/92	08 22	43.4	310	5.17	13.5	1.03	76.6	19.7	
7	1	3	1		10/27/92	12 53	45.2	245	4.08	11.1	2.63	237	61.2	3
7	1	3	2		10/27/92	12 59	42.6	244	4.07	10.4	2.56	246	63.5	
7	1	3	3		10/27/92	13 05	45.6	243	4.05	11.1	3.76	339	87.4	
7	1	3	3	R	10/27/92	13 08	42.6	241	4.02	10.3	3.39	330	85.1	
7	1	3	4		10/27/92	13 15	44.8	239	3.98	10.7	ND	ND	ND	
7	1	3	5		10/27/92	13 20	45.2	237	3.95	10.7	ND	ND	ND	
7	1	3	6		10/27/92	13 25	43.7	235	3.92	10.3	ND	ND	ND	
7	1	3	7		10/27/92	13 30	45.6	234	3.90	10.7	ND	ND	ND	
7	1	3	8		10/27/92	13 34	43	233	3.88	10.0	ND	ND	ND	
8	1	4	1		10/27/92	17 01	45.9	247	4.12	11.3	2.49	220	56.6	
8	1	4	2		10/27/92	17 04	41.9	253	4.22	10.6	2	189	48.6	
8	1	4	3		10/27/92	17 09	44.1	255	4.25	11.2	1.67	149	38.3	
8	1	4	3	R	10/27/92	17 09	43	255	4.25	11.0	1.24	113	29.1	
8	1	4	4		10/27/92	17 15	44.4	261	4.35	11.6	ND	ND	ND	
8	1	4	5		10/27/92	17 18	45.2	265	4.42	12.0	7.87	657	169	
8	1	4	6		10/27/92	17 21	44.4	272	4.53	12.1	ND	ND	ND	
8	1	4	7		10/27/92	17 25	45.6	278	4.63	12.7	ND	ND	ND	
8	1	4	8		10/27/92	17 28	42.6	281	4.68	12.0	0.96	80.2	20.7	
9	1	5	1		10/27/92	21 13	18.8	526	8.77	9.9	2.53	256	65.9	
9	1	5	2		10/27/92	21 19	19.4	528	8.80	10.2	3.27	319	82.2	
9	1	5	3		10/27/92	21 27	19.6	147	2.45	2.9	1.07	371	95.7	4
9	1	5	3		10/27/92	23 57	20.1	374	6.23	7.5	3.1	412	106	4
9	1	5	4		10/27/92	21 38	20.1	518	8.63	10.4	ND	ND	ND	
9	1	5	5		10/27/92	21 50	21.4	509	8.48	10.9	ND	ND	ND	
9	1	5	6		10/27/92	21 58	22.8	504	8.40	11.5	ND	ND	ND	
9	1	5	7		10/27/92	22 05	22.8	501	8.35	11.4	ND	ND	ND	

Appendix II. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Tarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
9	1	5	8		10/27/92	22 12	23.1	500	8.33	11.6	ND	ND	ND	
10	2	1	1		10/28/92	06 04	22.4	278	4.63	6.2	1.36	218	56.3	
10	2	1	2		10/28/92	06 07	23.1	279	4.65	6.4	0.76	118	30.4	
10	2	1	3		10/28/92	06 11	19.6	284	4.73	5.6	2	359	92.6	
10	2	1	4		10/28/92	06 17	21.1	286	4.77	6.0	ND	ND	ND	
10	2	1	5		10/28/92	06 20	22.6	284	4.73	6.4	0.24	37.4	9.63	
10	2	1	6		10/28/92	06 23	22.1	286	4.77	6.3	ND	ND	ND	
10	2	1	7		10/28/92	06 27	23.1	287	4.78	6.6	ND	ND	ND	
10	2	1	8		10/28/92	06 33	24.6	282	4.70	6.9	ND	ND	ND	
10	2	1	8	R	10/28/92	06 36	23.6	279	4.65	6.6	ND	ND	ND	
11	2	2	1		10/28/92	12 50	20.1	514	8.57	10.3	1.53	148	38.2	
11	2	2	2		10/28/92	12 54	23.6	514	8.57	12.1	1.42	117	30.2	
11	2	2	3		10/28/92	12 59	20.6	514	8.57	10.6	2.02	191	49.2	
11	2	2	4		10/28/92	13 02	20.6	517	8.62	10.7	0.48	45.1	11.6	
11	2	2	5		10/28/92	13 04	24.6	522	8.70	12.8	0.87	67.8	17.5	
11	2	2	6		10/28/92	13 10	22.6	522	8.70	11.8	0.43	36.4	9.39	
11	2	2	7		10/28/92	13 13	23.1	526	8.77	12.2	ND	ND	ND	
11	2	2	7	R	10/28/92	13 20	23.6	519	8.65	12.2	0.33	26.9	6.94	
11	2	2	8		10/28/92	13 15	22.6	532	8.87	12.0	ND	ND	ND	
12	2	3	1		10/28/92	21 25	16.6	530	8.83	8.8	1.17	133	34.3	5
12	2	3	2		10/28/92	21 30	18.8	531	8.85	10.0	0.51	51.1	13.2	5
12	2	3	3		10/28/92	21 34	21.1	533	8.88	11.2	1.99	177	45.6	
12	2	3	3	R	10/28/92	21 35	21.1	242	4.03	5.1	1.06	208	53.5	2
12	2	3	4		10/28/92	21 41	21.6	534	8.90	11.5	3.22	279	71.9	
12	2	3	5		10/28/92	21 47	20.6	533	8.88	11.0	2.52	230	59.1	2
12	2	3	6		10/28/92	21 55	23.6	529	8.82	12.5	0.62	49.7	12.8	
12	2	3	7		10/28/92	22 03	25.1	522	8.70	13.1	0.56	42.7	11.0	
12	2	3	8		10/28/92	22 09	25.6	517	8.62	13.2	0.9	68.0	17.5	
13	3	1	1		10/29/92	06 15	25.8	249	4.15	6.4	ND	ND	ND	5
13	3	1	2		10/29/92	06 20	23.9	250	4.17	6.0	ND	ND	ND	5
13	3	1	3		10/29/92	06 33	20.6	241	4.02	5.0	ND	ND	ND	
13	3	1	4		10/29/92	06 35	21.1	243	4.05	5.1	0.27	52.7	13.6	
13	3	1	5		10/29/92	06 40	28.9	240	4.00	6.9	0.51	73.5	18.9	
13	3	1	6		10/29/92	06 44	24.1	237	3.95	5.7	0.22	38.5	9.92	
13	3	1	7		10/29/92	06 45	24.1	239	3.98	5.8	ND	ND	ND	
13	3	1	8		10/29/92	06 47	24.4	240	4.00	5.9	ND	ND	ND	
13	3	1	8	R	10/29/92	06 47	18.8	239	3.98	4.5	ND	ND	ND	
14	3	2	1		10/29/92	12 40	20.4	519	8.65	10.6	1	94.5	24.3	
14	3	2	2		10/29/92	12 43	20.1	517	8.62	10.4	0.58	55.8	14.4	
14	3	2	3		10/29/92	12 46	22.1	524	8.73	11.6	0.96	82.9	21.4	
14	3	2	4		10/29/92	12 49	23.1	533	8.88	12.3	0.3	24.4	6.28	

Appendix II. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Tarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
14	3	2	5		10/29/92	12 51	21.2	538	8.97	11.4	0.86	75.4	19.4	
14	3	2	6		10/29/92	12 54	25.6	538	8.97	13.8	0.79	57.4	14.8	
14	3	2	7		10/29/92	12 56	25.1	541	9.02	13.6	0.74	54.5	14.0	
14	3	2	8		10/29/92	12 56	24.8	544	9.07	13.5	0.4	29.6	7.64	
15	3	3	1		10/29/92	21 20	20.8	522	8.70	10.9	1.17	108	27.8	
15	3	3	2		10/29/92	21 25	19.8	521	8.68	10.3	1.54	149	38.5	
15	3	3	3		10/29/92	21 31	20.1	519	8.65	10.4	1.81	174	44.7	
15	3	3	3	R	10/29/92	21 32	19.6	518	8.63	10.2	1.74	171	44.2	
15	3	3	4		10/29/92	21 43	24.1	513	8.55	12.4	1.39	112	29.0	
15	3	3	5		10/29/92	21 49	23.1	512	8.53	11.8	1.21	102	26.4	
15	3	3	6		10/29/92	21 52	20.8	513	8.55	10.7	0.8	75.0	19.3	
15	3	3	7		10/29/92	21 58	20.8	511	8.52	10.6	0.3	28.2	7.27	
15	3	3	8		10/29/92	22 01	21.1	511	8.52	10.8	0.41	38.0	9.80	
16	4	1	1		10/30/92	06 03	19.8	237	3.95	4.7	0.63	134	34.6	
16	4	1	2		10/30/92	06 07	20.4	236	3.93	4.8	0.43	89.3	23.0	
16	4	1	3		10/30/92	06 12	21.1	237	3.95	5.0	0.55	110	28.3	
16	4	1	3	R	10/30/92	06 13	20.4	236	3.93	4.8	0.54	112	28.9	
16	4	1	4		10/30/92	06 18	19.4	235	3.92	4.6	ND	ND	ND	
16	4	1	5		10/30/92	06 21	19.1	233	3.88	4.5	ND	ND	ND	
16	4	1	6		10/30/92	06 26	18.3	231	3.85	4.2	ND	ND	ND	
16	4	1	7		10/30/92	06 30	19.8	231	3.85	4.6	ND	ND	ND	
16	4	1	8		10/30/92	06 34	20.8	231	3.85	4.8	ND	ND	ND	
17	4	2	1		10/30/92	12 43	21.8	521	8.68	11.4	1.05	92.4	23.8	
17	4	2	2		10/30/92	12 46	18.6	523	8.72	9.7	0.92	94.6	24.4	
17	4	2	2	R	10/30/92	12 46	17.8	523	8.72	9.3	0.87	93.5	24.1	
17	4	2	3		10/30/92	12 52	18.8	523	8.72	9.8	1.77	180	46.4	
17	4	2	4		10/30/92	12 56	18.8	524	8.73	9.9	ND	ND	ND	
17	4	2	5		10/30/92	13 00	17.2	525	8.75	9.0	ND	ND	ND	
17	4	2	6		10/30/92	13 02	19.4	528	8.80	10.2	ND	ND	ND	
17	4	2	7		10/30/92	13 05	20.4	530	8.83	10.8	ND	ND	ND	
17	4	2	8		10/30/92	13 10	21.1	535	8.92	11.3	ND	ND	ND	5
18	4	3	1		10/30/92	21 24	21.4	533	8.88	11.4	ND	ND	ND	
18	4	3	2		10/30/92	21 30	20.8	533	8.88	11.1	ND	ND	ND	
18	4	3	3		10/30/92	21 36	22.6	530	8.83	12.0	1.03	86.0	22.2	
18	4	3	4		10/30/92	21 41	20.8	529	8.82	11.0	1.71	155	40.0	
18	4	3	5		10/30/92	21 46	21.1	528	8.80	11.1	1.58	142	36.5	
18	4	3	6		10/30/92	21 52	21.8	526	8.77	11.5	0.54	47.1	12.1	
18	4	3	7		10/30/92	21 56	21.1	527	8.78	11.1	ND	ND	ND	
18	4	3	7	R	10/30/92	21 59	22.6	523	8.72	11.8	ND	ND	ND	
18	4	3	8		10/30/92	22 07	23.4	520	8.67	12.2	ND	ND	ND	
19	5	1	1		10/31/92	06 19	22.1	246	4.10	5.4	ND	ND	ND	

Appendix II. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Tarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
19	5	1	2		10/31/92	06 24	21.8	245	4.08	5.3	ND	ND	ND	
19	5	1	3		10/31/92	06 28	23.4	244	4.07	5.7	ND	ND	ND	
19	5	1	4		10/31/92	06 31	20.4	244	4.07	5.0	ND	ND	ND	
19	5	1	5		10/31/92	06 36	21.8	253	4.22	5.5	0.48	87.0	22.4	
19	5	1	6		10/31/92	06 38	23.2	249	4.15	5.8	0.39	67.5	17.4	
19	5	1	6	R	10/31/92	06 46	21.6	239	3.98	5.2	ND	ND	ND	
19	5	1	7		10/31/92	06 44	23.4	246	4.10	5.8	ND	ND	ND	
19	5	1	8		10/31/92	06 50	26.1	245	4.08	6.4	ND	ND	ND	
20	5	2	1		10/31/92	13 07	21.1	509	8.48	10.7	1.33	124	31.9	
20	5	2	2		10/31/92	13 10	21.1	511	8.52	10.8	0.59	54.7	14.1	
20	5	2	3		10/31/92	13 12	21.8	514	8.57	11.2	1.34	120	30.8	
20	5	2	4		10/31/92	13 15	19.6	518	8.63	10.2	0.74	72.9	18.8	
20	5	2	5		10/31/92	13 19	22.6	520	8.67	11.8	0.78	66.4	17.1	6
20	5	2	6		10/31/92	13 21	21.1	251	4.18	5.3	ND	ND	ND	
20	5	2	7		10/31/92	13 25	20.1	529	8.82	10.6	0.26	24.5	6.30	
20	5	2	8		10/31/92	13 28	22.4	530	8.83	11.9	0.32	27.0	6.94	
21	5	3	1		10/31/92	21 38	23.6	537	8.95	12.7	0.53	41.8	10.8	
21	5	3	2		10/31/92	21 42	20.4	537	8.95	11.0	0.35	31.9	8.23	
21	5	3	3		10/31/92	21 48	22.4	536	8.93	12.0	1.69	141	36.3	
21	5	3	3	R	10/31/92	21 49	23.6	535	8.92	12.6	1.62	128	33.1	
21	5	3	4		10/31/92	21 55	21.6	532	8.87	11.5	1.27	111	28.5	
21	5	3	5		10/31/92	22 00	22.8	529	8.82	12.1	1.3	108	27.8	
21	5	3	6		10/31/92	22 09	22.1	524	8.73	11.6	0.57	49.2	12.7	
21	5	3	7		10/31/92	22 16	21.4	522	8.70	11.2	0.32	28.6	7.38	
21	5	3	8		10/31/92	22 20	24.4	521	8.68	12.7	ND	ND	ND	3

Footnotes

a. Sampling sequence is the sequence of samples collected from beginning to end of the study.

b. Sampling periods were numbered sequentially within day post-application.

c. Sampler location. Samplers 1, 3, 5, and 7 were at 10 m; 2, 4, 6, and 8 were at about 50 m.

d. B = background sample, collected prior to fumigation.

e. ND = none detected. Detection limit was 0.2 ug per sampling tube.

f. R = replicate (collocated) sample.

Notes

1. Breakthrough from primary to backup tube occurred. Total residue in both tubes reported.
2. Dead Battery. Sampling interval estimated.
3. Broken or missing backup tube.
4. 0.72µg(primary) + 0.35µg(backup). Primary tube fell off ca. 100 min after sampling began. Backup tube ran an additional 47 min. New tubes were put on at 23:57.
5. Rotometer reading not reported; flow rate estimated from start flow and previous sample ending flow.
6. Primary tube fell off near end of run; backup tube was ND.

Appendix III. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Untarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
0	-1	0	0	B[d]	10/26/92	13 26	43	231	3.85	9.93	ND[e]	ND	ND	
0	-1	0	0	B	10/26/92	13 26	45.2	229	3.82	10.35	ND	ND	ND	
1	0	1	1		10/27/92	09 48	43.4	220	3.67	9.55	5.61	588	139	
1	0	1	1	R[f]	10/27/92	09 48	43.7	220	3.67	9.61	4.95	515	121	
1	0	1	2		10/27/92	09 51	44.4	224	3.73	9.95	2.1	211	49.8	
1	0	1	3		10/27/92	09 54	42.2	228	3.80	9.62	0.44	45.7	10.8	
1	0	1	4		10/27/92	09 57	42.6	238	3.97	10.14	ND	ND	ND	
1	0	1	5		10/27/92	10 00	44.4	240	4.00	10.66	0.65	61.0	14.4	
1	0	1	6		10/27/92	10 04	44.1	240	4.00	10.58	ND	ND	ND	
1	0	1	7		10/27/92	10 02	39.7	246	4.10	9.77	1.83	187	44.2	
1	0	1	8		10/27/92	10 04	43	247	4.12	10.62	4.42	416	98.2	
2	0	2	1		10/27/92	13 46	41.9	268	4.47	11.23	30.9	2752	649	
2	0	2	1	R	10/27/92	13 46	44.4	269	4.48	11.94	34.5	2889	682	
2	0	2	2		10/27/92	13 46	44	275	4.58	12.10	14.78	1221	288	1
2	0	2	3		10/27/92	13 43	38.2	285	4.75	10.89	0.65	59.7	14.1	
2	0	2	4		10/27/92	13 56	41.5	277	4.62	11.50	ND	ND	ND	
2	0	2	5		10/27/92	14 01	40.8	276	4.60	11.26	ND	ND	ND	
2	0	2	6		10/27/92	14 06	45.6	275	4.58	12.54	ND	ND	ND	
2	0	2	7		10/27/92	14 09	37.5	278	4.63	10.43	2.30	221	52.1	
2	0	2	8		10/27/92	14 13	41.5	278	4.63	11.54	20.5	1777	419	
3	0	3	1		10/27/92	18 16	41.9	266	4.43	11.15	33.2	2979	703	
3	0	3	2		10/27/92	18 24	43	262	4.37	11.27	19.9	1766	417	
3	0	3	3		10/27/92	18 29	41.2	262	4.37	10.79	1.38	128	30.2	
3	0	3	4		10/27/92	18 34	43	261	4.35	11.22	ND	ND	ND	
3	0	3	5		10/27/92	18 38	42.6	261	4.35	11.12	ND	ND	ND	
3	0	3	6		10/27/92	18 42	44.8	260	4.33	11.65	ND	ND	ND	
3	0	3	7	R	10/27/92	18 48	36.4	259	4.32	9.43	3.06	325	76.6	
3	0	3	8		10/27/92	18 52	41.9	266	4.43	11.15	26.6	2387	563	
3	0	3	8	R	10/27/92	18 54	45.6	262	4.37	11.95	22.6	1892	446	
4	0	4	1		10/27/92	22 43	42.3	265	4.42	11.21	18	1606	379	
4	0	4	2		10/27/92	22 47	44.4	271	4.52	12.03	16.1	1338	316	
4	0	4	3		10/27/92	22 51	41.6	271	4.52	11.27	1.83	162	38.3	
4	0	4	4		10/27/92	22 56	42.6	270	4.50	11.50	ND	ND	ND	
4	0	4	5		10/27/92	22 59	44.4	270	4.50	11.99	ND	ND	ND	
4	0	4	6		10/27/92	23 02	46.2	270	4.50	12.47	ND	ND	ND	
4	0	4	7	R	10/27/92	23 15	46.3	261	4.35	12.08	2.14	177	41.8	
4	0	4	7		10/27/92	23 12	46.6	265	4.42	12.35	2.35	190	44.9	
4	0	4	8		10/27/92	23 19	43.4	263	4.38	11.41	16.1	1411	333	
5	1	1	1		10/28/92	03 12	40.8	276	4.60	11.26	15.7	1394	329	
5	1	1	2		10/28/92	03 18	44.4	278	4.63	12.34	10.4	843	199	
5	1	1	3		10/28/92	03 22	44.8	278	4.63	12.45	7.33	589	139	

Appendix III. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Untarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
5	1	1	4		10/28/92	03 27	43	288	4.80	12.38	ND	ND	ND	
5	1	1	5		10/28/92	03 30	44.4	289	4.82	12.83	ND	ND	ND	
5	1	1	6		10/28/92	03 36	46.2	289	4.82	13.35	ND	ND	ND	
5	1	1	7		10/28/92	03 39	45.2	290	4.83	13.11	1.19	90.8	21.4	
5	1	1	8		10/28/92	03 42	44.4	292	4.87	12.96	8.29	639	151	
5	1	1	8	R	10/28/92	03 44	45.2	289	4.82	13.06	8.45	647	153	
6	1	2	1		10/28/92	07 54	42.3	273	4.55	11.55	3.4	294	69.5	
6	1	2	2		10/28/92	07 57	45.2	276	4.60	12.48	2.41	193	45.6	
6	1	2	3		10/28/92	08 01	43.7	276	4.60	12.06	1.22	101	23.9	1
6	1	2	4		10/28/92	08 16	43	267	4.45	11.48	ND	ND	ND	2
6	1	2	5		10/28/92	08 21	45.2	265	4.42	11.98	ND	ND	ND	
6	1	2	6		10/28/92	08 21	48.1	268	4.47	12.89	ND	ND	ND	
6	1	2	7		10/28/92	08 30	47.4	271	4.52	12.85	0.20	15.6	3.67	
6	1	2	8	R	10/28/92	08 36	43.7	258	4.30	11.27	2.38	211	49.8	
6	1	2	8		10/28/92	08 37	43.7	258	4.30	11.27	2.43	216	50.9	
7	1	3	1		10/28/92	12 30	43.7	228	3.80	9.96	2.62	263	62.0	
7	1	3	2		10/28/92	12 34	45.2	227	3.78	10.26	2.03	198	46.7	
7	1	3	3		10/28/92	12 39	43.7	228	3.80	9.96	0.22	22.1	5.21	
7	1	3	4		10/28/92	12 44	42.3	230	3.83	9.73	ND	ND	ND	
7	1	3	5		10/28/92	12 48	45.2	228	3.80	10.31	ND	ND	ND	
7	1	3	6		10/28/92	12 51	46.6	228	3.80	10.62	ND	ND	ND	
7	1	3	7		10/28/92	13 03	47.4	223	3.72	10.57	0.23	21.8	5.13	
7	1	3	7	R	10/28/92	13 03	44.4	221	3.68	9.81	0.21	21.4	5.05	
7	1	3	8		10/28/92	12 57	46.6	235	3.92	10.95	2.06	188	44.4	
8	1	4	1		10/28/92	16 19	43.4	259	4.32	11.24	3.43	305	72.0	
8	1	4	2		10/28/92	16 24	45.2	260	4.33	11.75	2.3	196	46.2	
8	1	4	3		10/28/92	16 28	40.8	263	4.38	10.73	7.07	659	155	
8	1	4	4		10/28/92	16 34	43	264	4.40	11.35	0.64	56.4	13.3	
8	1	4	5		10/28/92	16 37	45.6	271	4.52	12.36	0.87	70.4	16.6	
8	1	4	6		10/28/92	16 42	46.2	270	4.50	12.47	ND	ND	ND	
8	1	4	7		10/28/92	16 47	44.8	272	4.53	12.19	ND	ND	ND	
8	1	4	7	R	10/28/92	16 49	48.1	268	4.47	12.89	ND	ND	ND	
8	1	4	8		10/28/92	16 53	46.6	274	4.57	12.77	1.5	117	27.7	
9	1	5	1		10/28/92	20 41	19.1	529	8.82	10.10	3.96	392	92.5	
9	1	5	2		10/28/92	20 46	20.4	528	8.80	10.77	1.85	172	40.5	
9	1	5	3		10/28/92	20 53	22.8	526	8.77	11.99	5.7	475	112	1
9	1	5	4	R	10/28/92	21 00	20.8	527	8.78	10.96	2.22	203	47.8	
9	1	5	4		10/28/92	21 02	21.1	526	8.77	11.10	2.12	191	45.1	
9	1	5	5		10/28/92	21 08	19.1	524	8.73	10.01	1.97	197	46.4	
9	1	5	6		10/28/92	21 13	19.8	522	8.70	10.34	0.42	40.6	9.59	
9	1	5	7		10/28/92	21 21	16.8	518	8.63	8.70	0.27	31.0	7.32	

Appendix III. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Untarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
9	1	5	8		10/28/92	21 29	16.4	515	8.58	8.45	2.61	309	72.9	
10	2	1	1		10/29/92	05 32	19.1	255	4.25	4.87	ND	ND	ND	
10	2	1	2		10/29/92	05 35	21.6	255	4.25	5.51	ND	ND	ND	
10	2	1	3		10/29/92	05 39	48.1	255	4.25	12.27	0.75	61.1	14.4	
10	2	1	4		10/29/92	05 48	19.1	254	4.23	4.85	0.5	103	24.3	
10	2	1	5		10/29/92	05 52	20.1	253	4.22	5.09	0.67	132	31.1	
10	2	1	6		10/29/92	05 55	18.6	252	4.20	4.69	0.24	51.2	12.1	
10	2	1	7		10/29/92	06 00	25.6	250	4.17	6.40	ND	ND	ND	
10	2	1	8		10/29/92	06 04	28.6	249	4.15	7.12	ND	ND	ND	
11	2	2	1		10/29/92	11 47	21.1	493	8.22	10.40	0.93	89.4	21.1	
11	2	2	2		10/29/92	11 47	21.4	497	8.28	10.64	0.65	61.1	14.4	
11	2	2	3		10/29/92	11 53	22.4	498	8.30	11.16	0.52	46.6	11.0	
11	2	2	4		10/29/92	11 55	23.1	508	8.47	11.73	0.25	21.3	5.03	
11	2	2	4	R	10/29/92	11 55	27.8	506	8.43	14.07	0.25	17.8	4.19	
11	2	2	5		10/29/92	11 58	20.8	505	8.42	10.50	0.62	59.0	13.9	
11	2	2	6		10/29/92	12 00	22.4	517	8.62	11.58	0.62	53.5	12.6	
11	2	2	7		10/29/92	12 02	26.4	519	8.65	13.70	1.25	91.2	21.5	
11	2	2	8		10/29/92	12 04	20.1	523	8.72	10.51	1.49	142	33.4	
12	2	3	1		10/29/92	20 00	19.1	548	9.13	10.47	2.07	198	46.7	
12	2	3	2		10/29/92	20 05	21.1	546	9.10	11.52	2.14	186	43.8	
12	2	3	3		10/29/92	20 12	23.4	545	9.08	12.75	3.62	284	67.0	1
12	2	3	4		10/29/92	20 27	22.1	536	8.93	11.85	0.87	73.4	17.3	
12	2	3	5		10/29/92	20 33	22.8	534	8.90	12.18	1.4	115	27.1	
12	2	3	5	R	10/29/92	20 34	22.1	535	8.92	11.82	1.21	102	24.1	
12	2	3	6		10/29/92	20 38	21.8	536	8.93	11.68	0.46	39.4	9.29	
12	2	3	7		10/29/92	20 41	18.6	539	8.98	10.03	0.55	54.9	12.9	
12	2	3	8		10/29/92	20 48	20.8	536	8.93	11.15	1.28	115	27.1	
13	3	1	1		10/30/92	05 08	20.4	247	4.12	5.04	0.42	83.4	19.7	
13	3	1	2		10/30/92	05 12	23.4	243	4.05	5.69	0.25	44.0	10.4	
13	3	1	3		10/30/92	05 18	22.1	247	4.12	5.46	0.25	45.8	10.8	
13	3	1	4		10/30/92	05 24	22.6	245	4.08	5.54	ND	ND	ND	
13	3	1	5		10/30/92	05 30	20.6	242	4.03	4.99	ND	ND	ND	
13	3	1	6		10/30/92	05 36	21.8	239	3.98	5.21	ND	ND	ND	
13	3	1	6	R	10/30/92	05 37	21.1	238	3.97	5.02	ND	ND	ND	
13	3	1	7		10/30/92	05 41	20.4	238	3.97	4.86	ND	ND	ND	
13	3	1	8		10/30/92	05 45	21.1	238	3.97	5.02	0.23	45.8	10.8	
14	3	2	1		10/30/92	12 01	20.4	504	8.40	10.28	1.2	117	27.5	
14	3	2	2		10/30/92	12 05	19.6	503	8.38	9.86	1.26	128	30.2	
14	3	2	3		10/30/92	12 10	19.6	506	8.43	9.92	0.25	25.2	5.95	
14	3	2	4		10/30/92	12 11	20.1	501	8.35	10.07	ND	ND	ND	
14	3	2	5		10/30/92	12 14	19.8	508	8.47	10.06	ND	ND	ND	

Appendix III. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Untarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
14	3	2	6		10/30/92	12 16	19.4	511	8.52	9.91	ND	ND	ND	
14	3	2	6	R	10/30/92	12 16	21.8	509	8.48	11.10	ND	ND	ND	
14	3	2	7		10/30/92	12 20	19.4	511	8.52	9.91	ND	ND	ND	
14	3	2	8		10/30/92	12 24	18.6	512	8.53	9.52	0.59	62.0	14.6	
15	3	3	1		10/30/92	20 25	20.8	526	8.77	10.94	0.57	52.1	12.3	
15	3	3	2		10/30/92	20 29	19.8	530	8.83	10.49	1.08	103	24.3	3
15	3	3	3		10/30/92	20 34	22.1	531	8.85	11.74	0.76	64.8	15.3	1
15	3	3	4		10/30/92	20 39	22.8	533	8.88	12.15	2.32	191	45.0	
15	3	3	5		10/30/92	20 42	23.6	536	8.93	12.65	2.45	194	45.7	
15	3	3	6		10/30/92	20 47	20.1	532	8.87	10.69	ND	ND	ND	
15	3	3	7		10/30/92	20 53	20.6	530	8.83	10.92	0.22	20.2	4.75	
15	3	3	8		10/30/92	20 57	22.4	533	8.88	11.94	0.3	25.1	5.93	
15	3	3	8	R	10/30/92	20 59	21.1	528	8.80	11.14	0.3	26.9	6.35	
16	4	1	1		10/31/92	05 15	20.1	255	4.25	5.13	ND	ND	ND	
16	4	1	2		10/31/92	05 20	21.6	255	4.25	5.51	ND	ND	ND	
16	4	1	3		10/31/92	05 26	25.6	253	4.22	6.48	0.23	35.5	8.38	
16	4	1	4		10/31/92	05 33	24.8	252	4.20	6.25	0.38	60.8	14.3	
16	4	1	5		10/31/92	05 36	24.6	250	4.17	6.15	0.47	76.4	18.0	
16	4	1	6		10/31/92	05 40	20.1	249	4.15	5.00	0.27	53.9	12.7	
16	4	1	6	R	10/31/92	05 55	20.4	235	3.92	4.79	0.23	48.0	11.3	
16	4	1	7		10/31/92	05 44	19.6	255	4.25	5.00	ND	ND	ND	
16	4	1	8		10/31/92	05 52	25.4	248	4.13	6.30	ND	ND	ND	
17	4	2	1		10/31/92	12 15	20.4	495	8.25	10.10	0.49	48.5	11.4	
17	4	2	2		10/31/92	12 18	20.8	496	8.27	10.32	0.52	50.4	11.9	
17	4	2	3		10/31/92	12 20	25.6	503	8.38	12.88	0.61	47.4	11.2	
17	4	2	3	R	10/31/92	12 21	21.4	502	8.37	10.74	0.43	40.0	9.44	
17	4	2	4		10/31/92	12 25	24.4	508	8.47	12.40	0.73	58.9	13.9	
17	4	2	5		10/31/92	12 27	23.8	512	8.53	12.19	0.51	41.9	9.87	
17	4	2	6		10/31/92	12 30	20.1	513	8.55	10.31	0.29	28.1	6.64	
17	4	2	7		10/31/92	12 34	20.1	513	8.55	10.31	ND	ND	ND	
17	4	2	8		10/31/92	12 37	24.6	517	8.62	12.72	0.45	35.4	8.35	
18	4	3	1		10/31/92	20 31	20.4	531	8.85	10.83	1.04	96.0	22.7	
18	4	3	2		10/31/92	20 37	21.4	533	8.88	11.41	0.73	64.0	15.1	
18	4	3	2	R	10/31/92	20 38	23.8	531	8.85	12.64	0.82	64.9	15.3	
18	4	3	3		10/31/92	20 46	21.8	532	8.87	11.60	1.17	101	23.8	
18	4	3	4		10/31/92	20 54	24.8	535	8.92	13.27	0.62	46.7	11.0	
18	4	3	5		10/31/92	21 00	26.6	539	8.98	14.34	1	69.7	16.5	
18	4	3	6		10/31/92	21 04	22.1	537	8.95	11.87	0.89	75.0	17.7	
18	4	3	7		10/31/92	21 08	28.1	534	8.90	15.01	1.2	80.0	18.9	
18	4	3	8		10/31/92	21 15	20.4	535	8.92	10.91	0.72	66.0	15.6	
18	4	3	9	FB	10/31/92	20 30	23	540	9.00	12.42	ND	ND	ND	4

Appendix III. Methyl Bromide Concentrations in Air Sampled 10 to 50 m From the Untarped Field.

Sampling Sequence[a]	Day Post-Application	Period Within Day[b]	Sampler Location[c]		Month/Day/Year	Time On	Flow Rate (ml/min)	Total Sampling Time (min)	Total Sampling Time (hours)	Total Volume (l)	Total µg	µg /m3	ppb	Notes
19	5	1	1		11/1/92	05 24	21.6	260	4.33	5.62	0.27	48.1	11.3	
19	5	1	2		11/1/92	05 32	21.8	254	4.23	5.54	0.23	41.5	9.80	
19	5	1	3		11/1/92	05 46	23.8	248	4.13	5.90	0.43	72.9	17.2	
19	5	1	4		11/1/92	05 51	28.4	248	4.13	7.04	ND	ND	ND	
19	5	1	4	R	11/1/92	05 52	23.8	248	4.13	5.90	ND	ND	ND	3
19	5	1	5		11/1/92	05 59	25.1	246	4.10	6.17	ND	ND	ND	
19	5	1	6		11/1/92	06 01	24.4	248	4.13	6.05	ND	ND	ND	
19	5	1	7		11/1/92	06 05	23.4	247	4.12	5.78	ND	ND	ND	
19	5	1	8		11/1/92	06 12	27.8	243	4.05	6.76	ND	ND	ND	

Footnotes

a. Sampling sequence is the sequence of samples collected from beginning to end of study.

b. Sampling periods were numbered sequentially within day post-application.

c. Sampler location. Samplers 1, 3, 5, and 7 were at 10 m; 2, 4, 6, and 8 were at about 50 m.

d. B = background sample, collected prior to fumigation.

e. ND = none detected. Detection limit was 0.2 ug per sampling tube.

f. R = replicate (co-located) sample.

Notes

1. Breakthrough from primary to backup tube occurred. Total residue in both tubes reported.
2. Rotometer reading not reported. Flow rate estimated from previous sample.
3. Broken or missing backup tube.
4. Field blank.

Appendix IV. Methyl Bromide Flux From the Tarped and Untarped Fields.

Data From Majewski, et al., 1995.